[Process to examine an object]

BACKGROUND OF THE INVENTION

A. Field of the Invention

The present invention relates generally to a process to examine at least one object, whereby properties of the object are detected by various measurements within a spatial[-]frequency space formed by spatial frequencies. Preferably, the various measurements take place at different times. The present invention may be used to analyze the properties of various objects, such as for example, any object that may be imaged, any object typically measured using magnetic resonance imaging or nuclear magnetic resonance techniques, etc.

B. Description of the Related Art

Examinations of the spatial[-]frequency space are employed in a wide array of technical fields. Since pulse spaces correspond to spatial[-]frequency spaces, the term "spatial frequency space" also encompasses pulse spaces. [The designation spatial-frequency space serves to clarify the fact that the invention also relates to a process in which no pulse transmission occurs.] A known problem encountered when imaging spatial[-]frequency spaces is that a very long measuring time is needed when a high local resolution is combined with a high spatial frequency resolution.

A keyhole process for solving this problem is known. In this process, a high-resolution image involving the detection of the entire spatial[-]frequency space is determined at least for one point in time. In one or more measuring steps, a central area of the spatial[-]frequency space is imaged that determines the contrast of the reconstructed image. Subsequently, the high-resolution image is mathematically linked to the recorded image(s) of the central areas of the spatial[-]frequency space in such a way that a high-resolution image having a contrast that corresponds to the point in time of the recording is determined for the other time or times.

This known process has the disadvantage that contrast changes between consecutive measurements can only be determined if they have a sufficiently large spatial extension. This disadvantage is particularly detrimental when functional parameters of the object are being detected. Thus, for instance, in functional magnetic resonance imaging, there is a need for parameters that influence nuclear magnetic resonance signals to be detected with the highest possible spatial resolution.

Thus, there is a need in the art for a process to examine the properties of an object within a spatial frequency space, especially the functional parameters of the object, that overcomes the problems of the related art.

SUMMARY OF THE INVENTION

The present invention [is based on the objective of creating] solves the problems of the related art by providing a process [with which it is possible to detect] for examining an object that enables detection of a change in the functional parameters of the object when the spatial areas affected by the change are relatively small. The process of the present invention occurs in the spatial frequency space. That is, no pulse transmission occurs in the process of the present invention.

[This objective is achieved according to the invention in that] More specifically, the process of the present invention solves the problems of the related art by taking various measurements [take place] in at least one shared area of the spatial[-]frequency space and, additionally, in areas of the spatial frequency space that are different from each other. Preferably, the measurements detect the spatial[-]frequency space in images taken at different times. In particular, the process of the present invention provides for examining areas of the spatial frequency space at rates of occurrence that differ

from each other. More preferably, the process of the present invention provides for examining areas of the spatial frequency space at three or more [, whereby preferably there are at least three] different rates of occurrence for detecting areas.

[It is advantageous for the measurements of the areas to take place with at least three different detection rates of occurrence.]

Preferably, at least one, for example [instance], centrally located area of the spatial frequency space is detected in several measurements while other areas are not detected at all, or are [else] only detected in a single measuring procedure. Preferably, [It is advantageous to carry out] the process is carried out in such a way that the overlapping areas cover a central region of the spatial[-]frequency space.

[An advantageous embodiment] In one aspect of the process of the present invention, [is characterized in that] the additional, but preferably not central, areas in the spatial[-]frequency space are at a distance from each other that is greater than their spatial [frequent] frequency extension in the direction of this distance. Preferably, [It is advantageous to carry out] the process is carried out in such a way that the other areas of the spatial[-]frequency space extend, at least partially, parallel to each other. More preferably, [Here, it is especially advantageous for] the disjunctive elements of the individual sets [to] extend, at least partially, parallel to each other in the spatial[-]frequency space.

In another aspect [An advantageous embodiment] of the process of the present invention, [is characterized in that] the measurements are carried out in such a way that a cycle is formed in which at least some of the areas of the spatial[-]frequency space that differ from each other are once again detected in additional measurements. In still another aspect of the process of the present invention, the detected areas [An advantageous embodiment to carry out the process is characterized in that

areas detected] form a disjunctive set in at least one measurement.

Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description. It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention, as claimed.

[Additional advantages, special features and practical improvements of the invention ensue from the subordinate claims and from the following presentation of a preferred embodiment of the invention with reference to the drawing.]

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus are not limitative of the present invention, and wherein:

Fig. 1 is a schematic diagram showing a process for detecting the properties of an object using various measurements within a spatial frequency space formed by spatial frequencies in accordance with an embodiment of the present invention.

DESCRIPTION OF AN EMBODIMENT OF THE PRESENT INVENTION

The following detailed description of the invention refers to the accompanying drawings. The

same reference numbers in different drawings identify the same or similar elements. Also, the following detailed description does not limit the invention. Instead, the scope of the invention is defined by the appended claims and equivalents thereof.

The process of the present invention for detecting the properties of an object using various measurements within a spatial frequency space formed by spatial frequencies is shown generally in Fig. 1. The [drawing] image shows the detection of a spatial[-]frequency space having, by way of example only, N × N points [as an example]. For purposes of simplifying the graphical representation, a two-dimensional depiction was chosen, although the invention is by no means restricted to the detection of two-dimensional spatial[-]frequency spaces, but rather, it is suitable to detect spatial frequency[-]spaces having any desired number of dimensions.

A first [measuring procedure] step of the process of the present invention detects a central area 1 as well as areas 10 (represented here in the form of solid lines) of the spatial[-]frequency space that are at a distance from the central area 1 [- represented here in the form of broken lines -], and that are preferably essentially parallel to the spatial[-]frequency space.

In a subsequent step of the process of the present invention, the central area 1 is detected once again. In addition, other areas 20 [-] (represented by the dash-dot lines) [-] of the spatial[-]frequency space that lie outside of the central area 1 are also detected. The other areas 20 of the spatial[-]frequency space preferably extend essentially parallel to each other and [anti-parallel] to the other areas 10 detected in the first [preceding measuring] step of the process. Other areas 20, however, preferably extend in a direction opposite the direction other areas 10 extend, as shown by the left arrows for other areas 20 and the right arrows for other areas 10.

Subsequently, the [measuring procedure] third step of the process of present invention is

[repeated] performed. In this [repetition] step, the central area 1 as well as other areas 30 [-] (indicated by the [dash-dot-dot] dotted lines) [-] of the spatial[-]frequency space are detected. The other areas 30 of the spatial frequency space preferably extend essentially parallel to each other and to the other areas 10, 20 detected in the first and second steps of the process, respectively. Other areas 30, however, also extend in a same direction as the direction other areas 10 extend, as shown by the right arrows for other areas 10 and 30.

By [means of merely selective detection of] selectively detecting the high-frequency data, the time advantage of a keyhole method is essentially maintained using the process of the present invention. Moreover, noise effects are suppressed in the process of the present invention. Furthermore, the images shown have a high spatial resolution corresponding to the overall images of the spatial[-]frequency space.

By way of example only and without limiting the scope of the present invention, it [It] is particularly advantageous to image a suitable SPARCE sequence. Preferably, an imaging pattern corresponds to a SPARCE sequence having the following formula:

SPARCE (f, n) = [N/2-n, N/2-f-n, N/2-2f-n,...(KEYHOLE)...-N/2+3f-n, -N/2+2f-n, -N/2+f-n]

Preferably [In an advantageous manner], the entire spatial[-]frequency space is imaged, whereby the spatial[-]frequency space can be considered, for example, to be an $N \times N$ image matrix. The image matrix has a slight covering of high spatial frequencies as well as a more thoroughly covered, so-called keyhole area. A SPARCE sequence, SPARCE <f, n>, contains indices f, n, wherein f stands for an image factor and n for a running time variable, whereby it applies that ($0 < n < f$).

By means of a relatively small or infrequent detection of areas having high spatial frequencies,

a time advantage is achieved with the process of the present invention, in addition to which the correlation between high-frequency noises is reduced, which is something particularly advantageous. Another improvement in the process of the present invention can be achieved with an even-numbered sampling factor f in that even and odd echoes are detected separately.

It will be apparent to those skilled in the art that various modifications and variations can be made in the process for detecting the properties of an object of the present invention and in construction of this process without departing from the scope or spirit of the invention.

Other embodiments of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope and spirit of the invention being indicated by the following claims.